

Chirped Pulse Reflectometry for High-Precision Measurements of Shock Velocity

D. M. Gold, A. Sullivan, R. Shepherd, J. Dunn, and R. Stewart
Lawrence Livermore National Laboratory
 Livermore, CA

Abstract

We present results of a high-precision, optical technique for measurement of megabar shock velocities in laser-driven materials. Chirped Pulse Reflectometry (CPR) uses a chirped laser probe pulse to detect the time at which a strong (ionizing) shock wave breaks out of a target. The chirp encodes the pulse spectrum with a proportional time history. A reflectivity change from ionization during shock breakout gates and modulates the spectrum, producing interference fringes which act as sub-100 fs time fiducials for the shock breakout time. Measuring breakout times in a stepped target with different thicknesses gives the velocity of the shock in that material. Accurate equation-of-state (EOS) data for many materials can be obtained by impedance-matching experiments¹ relative to a standard material, e.g. Al, with a known EOS.

CPR was tested by using an aluminum target ionized by a 100 fs, 10^{15} - 10^{16} W/cm² pulse to simulate the reflectivity change (~50% at $T_e = 1$ -10 eV) produced by a ionizing shock breakout. A 100 fs, 800 nm probe pulse chirped in a grating pair stretcher to ~20 ps and reflected from the plasma was imaged onto a spectrometer slit. Spectral interference fringes produced by the reflective gating provided timing fiducials accurate to <100 fs. Breakout times are spatially resolved along one dimension of the plasma by imaging onto the spectrometer entrance slit. The measured >3000:1 signal-to-noise ratio allows Fourier inversion of spectral results for a complete shock breakout time history. Application of CPR measurements to megabar shocks produced by the 1 ns Janus laser facility will also be discussed.

The current capability of shock velocity measurements relies on direct viewing or interferometric techniques² with fast optical or x-ray streak cameras. Streak cameras have practical time resolutions of a few picoseconds, are typically noisy, of limited sensitivity and dynamic range, and have nonlinear distortions in sweep speed which must be characterized on a shot-by-shot basis. CPR would avoid these problems, while increasing the precision of shock velocity measurements by more than one order of magnitude. This

¹M. Koenig, *et al.*, Phys. Rev. Lett. **74**, 2260 (1995).

²M. Koenig, *et al.*, Phys. Rev. Lett. **74**, 2260 (1995); A. Ng, D. Parfeniuk, P. Celliers, and L. DaSilva, Phys. Rev. Lett. **57**, 1595 (1986); J.R. Asay and L.M. Barker, J. App. Phys. **45**, 2540 (1974).

would allow sensitive discrimination between EOS models³ used in hydrodynamic and thermodynamic codes.

* Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-ENG-48

³B.I. Bennett *et. al.*, LANL Report No. LA-7130, 1978 (unpublished); *T-4 Handbook of Material Properties Data Bases: Vol. Ic, Equations of State*, edited by K.S. Holian LANL Report No. LA-10160-MS, UC-34, 1984 (unpublished); R.M. More, K.H. Warren, D.A. Young, and G.B. Zimmerman, *Phys. Fluids* **31**, 3059 (1988).